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ORIGINAL ARTICLE

Cultural Geology, Cultural Biology, Cultural Taxonomy, and the Intangible Geoheritage as New Strategies for Geoconservation

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Abstract
Nature conservation largely focuses on biological assets, treating geodiversity as a minor concern. We formally define here cultural geology, cultural biology, and cultural taxonomy, as emerging scientific fields focused on assessing the impact of natural sciences and natural features in the culture. We propose them as fundamental tools for innovative geoconservation strategies, since their integrated application provides a new pathway to achieve a holistic nature conservation, especially when combined with other areas as cultural paleontology and geomythology. These new fields can successfully assist in protecting geoheritage from a broader array of hazards. One of these potentials is to improve the scientist-population communication, leading to a more integrated perception of the geodiversity and biodiversity relevance as natural and cultural heritage, fostering an active role of the public in geoconservation approaches. However, as specified in this paper, these fields are not synonymous of science popularization or education. We also expect to show that adopting the Geoheritage wider definition of Ponciano et al. (Editora Interciência, Rio de Janeiro 4:853–869, 2011) is a better way of achieving the desired results in geoconservation. Finally, we propose that very influential geomyths and geodiversity-centered audiovisual products should be encompassed within an intangible geoheritage category, as a Ponciano et al.'s (Editora Interciência, Rio de Janeiro 4:853–869, 2011) ex situ geological heritage subset, in order to analyze the cultural impact of abiotic features in society under the heritage perspective.

Keywords Cultural paleontology · Cultural zoology · Geomythology · Paleontological heritage · Science popularization · Nature conservation

Introduction

Nature conservation approaches tend to be extremely biased toward biology. The abiotic elements are generally neglected or receive less attention. Even the papers that "call for inclusive conservation" do not highlight geodiversity in their strategy (Tallis and Lubchenco 2014). Further, when debating the conservation science concept (a broader class from which conservation biology branches), Kareiva and Mariver (2012) have heavily focused on biodiversity and how it intertwined with the social environment, but not even citing geodiversity. Nevertheless, some proposals to promote a holistic nature conservation were made (e.g., Goetel 1966; Gray et al. 2013; Brilha et al. 2018; Schrodt et al. 2019), but they almost invariably came only from geoscientists, showing a still marginalized place for geodiversity among the environment protection strategies. In addition, the lack of geology lessons in elementary and high school classes in many countries (Brazil, for example) leave these data only to universities or to unprepared biology or geography teachers that address the theme fragmentarily (Carneiro et al. 2004; Carneiro and Barbosa 2005; Compiani 2005; Garcia et al. 2014; Duarte et al. 2019). In most schools, the traditional approaches used in the educational books are also some of the reasons related with this bias (Morais 2007; Mandu and Morais 2013), explaining why people tend to demonstrate less familiarity and a primary resistance to geosciences.

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In museology, the integral museum concept has arisen as a way to musealize (communicate, protect, and survey) all kinds of heritage of a given place, aiming to connect people to nature and culture, while integrating and taking into account the social reality of local people and institutions (Scheiner 2012). According to Scheiner (2012), it is linked to integral heritage, which generally concerns understanding heritage as composed of cultural and natural assets, the latter including both abiotic and biotic components. This notion is twice as holistic since it comprises an integrative view of nature as well as an integrative view of heritage. Finally, "it is considered, therefore, that only the fusion of the tangible and intangible constitutes the Integral Heritage" (ICOFOM LAM, 2006, p. 40). The intangible cultural heritage is defined as "the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity" (UNESCO 2003).

Being aware of these issues (neglecting geodiversity in nature conservation approaches) and ideas (integral heritage and intangible cultural heritage), we propose here some new scientific fields and concepts, besides formally defining existing ones, in order to bring people closer to geology and to foster the conservation of the nature as a whole. These fields study how natural elements and human culture are related and provide raw material for thinking of ways to protect nature by integrating the social reality of people with the natural assets, similarly to the integral heritage and integral museum concepts. A less hermetic, more integrative view of geoheritage is also advocated in this paper, so that geomyths are included in this category.

We begin by erecting and defining a new scientific field called cultural geology, whose goal is to identify how geology-related elements are presented in cultural manifestations (what may provide many applications, including formulating the best geoconservation strategies accordingly with the target public). After, we formally define cultural biology, an existing field which still lacks a definition. Cultural biology is proposed as a counterpart of cultural geology and, as well as the latter, may be applied in different manners, such as promoting a holistic nature conservation. We also briefly comment on a cultural biology subfield (cultural zoology) and on cultural paleontology, an already defined field of science that further highlights the potential of cultural biology and cultural geology to provide new strategies for the conservation of nature as a whole. Since we defend further in this paper that culturally significant geodiversity elements, including geomyths, should be considered geoheritage, in order to promote more efficient geoconservation strategies (see "The Intangible Geoheritage category" topic), we also discuss briefly on the geomythology concept (in the next topic). An important subfield of biology and paleontology, taxonomy may be co-opted by nature conservation approaches by means of identifying the biological identity of cultural objects (e.g., characters, mythological creatures), using them as mechanisms for teaching people about natural assets and their roles, in addition to stimulating a cultural identity of the population toward these objects. Furthermore, taxonomy may be used to bring people closer to science by making them aware their popular knowledge can support the scientific field (see the "Emergent Strategies to promote geoconservation" and "Cultural Taxonomy" topics). In the first one, we discuss more extensively on how studying the manifestation of biology and geology-related objects in human culture (and therefore fields like cultural biology, cultural geology, cultural taxonomy, etc.) is necessary for generating science identity and developing conservation strategies.

However, as we reiterate at the end of this paper, these fields are not synonyms of science popularization/disclosure or teaching, as well as they do not necessarily need to be applied on geoconservation strategies. They are, by definition, fields that are dedicated to study how elements related to geology and biology disciplines are present in cultural manifestations, therefore, being basic sciences instead of applied sciences. But it does not contradict our premise (to foster a holistic nature conservation and to achieve better geoconservation strategies) since we focus throughout this paper on how the basic principles gathered from these basic sciences are able to be applied to solve social issues in society, in the same manner paleontology is not a field of science dedicated to contribute to the advances in the medicine or the aeronautics fields, but its gathered information may have applications in both of them (e.g., Chatterjee et al. 2010; Roberts et al. 2011; Aureliano et al. 2021).

Cultural Geology

We name and define here cultural geology as a branch of the earth sciences dedicated to study the influence of geodiversity elements and geology-related concepts, theories, data, or people in cultural manifestations. Gray (2004) proposes geodiversity as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems." His definition is adopted here since it does not solely refers to physical objects but also encompasses their originating processes, as it is the case of dunes-forming wind regimes,

Fig. 1 Some examples of minerals presence in audiovisual products: (**A**) Gems in Castle of Illusion Starring Mickey Mouse game (1990); (**B**) Diamond-like gem in remastered version (2017) of a Crash Bandicoot first trilogy game; (**C**) Amethyst in a Crash Bandicoot first trilogy game (1996–1998); (**D**) Diamond-like gems in Spyro the Dragon game (1998). Images retrieved from Google Images website

which must be conserved to maintain the landscape (Brocx and Semeniuk 2007). We can find Geology in various cultural manifestations, including the association between fossils (and their reconstitutions) and myths. These relations will be discussed further in the "Cultural Paleontology" and the "Geomythology" sections. In this topic, we are going to focus on minerals and mineraloids, but we consider cultural paleontology and geomythology as part of cultural geology (Fig. 5). As such, throughout this topic, we are going to provide short analyses of the presence and symbolisms of these elements in human culture in order to exemplify cultural geology studies as well as to show how important are geodiversity elements to culture.

Minerals generally bear a power symbolism in our culture, as we can see in some examples (Fig. 1). Through conspicuous treasure symbolisms, all these examples validate minerals and mineraloids as related with power, success, victory, and/or achievement of objectives. In many places, traditional healing practices used minerals and mineraloids in treatments to "cure" diseases, and we can also identify a cultural activity in the people names chosen after them (Amber, Amethyst, Crystal, Jade, Pearl, Ruby, Garnet, Jasper, Sapphire, etc.). Usually people who hold these geodiversity elements want to obtain something very treasured (fortune, unlock new levels in the games, avoiding the evil, health, longevity, a beautiful and successful son/daughter, etc.). The frequent association of these elements with power and success is likely a consequence of them being historically assigned as financial-valued objects, tied in many cases to the need of mining activities in order to reach them. Rarity, esthetic appeal, and durability of many minerals made them commercially valuable objects, associated also with wealth and happiness.

This is clear in some Brazilian underprivileged states from North and Northeast regions, where many problems to reach geoconservation goals exist. When the residents notice geoscientists assessing and extracting unprofitable material from fossil sites (as well as geosites, as glacial striated pavements, with scientific value), local people commonly wait researchers leave to quarry on these outcrops, looking for gold or something economically valuable to extract from these rocks, a clear signal of digging/mining influence in their imaginary associated with wealth (Ponciano et al. 2011; Mansur et al. 2013). In the USA, Californian natives also have been mining and subsequently trading obsidian so intensively for millennia that this rock is considered the first widely marketed geodiversity resource in the region (Hodgson 2007).

Additionally, a religious correlation must be taken into account for inducing this power and spiritual symbolism, as people admire geodiversity objects fallen from the sky such as meteorites or pyroclastic rocks (D'Orazio 2007). Yuki people, natives from California, believe *Milili* spirit throws obsidian stones from the sky to the ground. Their shamans use blades made of this rock in their ceremonies (including healing rituals) because they believe in these stones divine significance. Hodgson (2007) argues this *Milili* myth is based on multiple past volcanic eruptions which may had thrown pyroclastic material (containing pumice or obsidian), besides forming obsidian on the ground, due to magma solidification. Stones had been largely used by ancient and current human groups as tools that aided in survival (success sign), such as obsidian arrowheads manufactured for hunting (power sign) (Hodgson 2007).

Other value assigned to minerals in cultural manifestation is the esthetic. Here, we can cite two examples regarding Disney cartoon Star vs. the forces of evil (2015–2019) and its expanded universe. For instance, in Nefcy et al.'s (2019) *The Magic Book of Spells*, Queens Butterfly's wands present some mineralogical (mineraloid included here) and rocky composition whose symbolism ranges from power/success (onyx, sapphire, and pearl needed for making magic wand work) to simply esthetic (moonstones, black onyx, agate, diamond, obsidian, quartz, gold, painite, etc.). Additionally, character Rhombulus possesses an exoskeleton consisting in quartz-like structures (hexagonal prism ending in a hexagonal pyramid). Although certainly an esthetic symbolism, it also bears a power (hardness) sign because he can aprisionate its adversaries in similar quartz-like crystals allegedly hard to break, suggesting its skeleton might represent a resistant armor.

In Avatar: The Last Airbender (2005–2008) cartoon both characters Sokka and Katara are imprisoned by a set of greenish to bluish quartz-like fictional mineral called jennamite, which shows hardness and a power symbolism as they are not able to break free on their own. Interestingly, jennamite depicts a mineral feature that might be unknown to many people: mineral growth. Minerals can grow, and a limiting factor which impossibilities this process is lack of room. In the case of jennamite, what slows its growth is time span.

A quick overlook on mineral presence in cultural manifestations tends to elect quartz-like and diamond-like objects the most illustrated components of mineralogy. Diamonds are rare, famous, and owning a real one is expensive, thus culturally providing a great success symbolism to this object. On the other hand, quartz is the second most abundant mineral on Earth and, considering bridgamite (the most abundant mineral on Earth) only occurs in inner layers of our planet and in shocked meteorites (Tschauner et al. 2014), it is the most relatable, notable, less expensive, and familiar mineral for non-geoscientists. Additionally, quartz, besides being common, it has an array of varieties, some bearing an esthetic appeal as amethyst, citrine, and quartzy layers in agate. Quartz also achieves greater proportions and it is often depicted as a very tall crystal in many audiovisual productions. An interesting cultural geology research would be to verify if quartz tends to be more oftenly represented under a simply esthetic symbol rather than a success one, in comparison to more expensive crystals (e.g., diamonds). Other geodiversity elements might be represented too. For example, mudstones are used to make Dirhhennia Butterfly's magic wand work (Nefcy et al. 2019). Granulometry is cited in Star vs. the forces of evil when a girl said she was too excited to learn everything about mud. Another example of granulometric parameters in culture is Sandman supervillain in Spider-Man franchise.

Cultural Biology

Since we advocate an integrative view of the nature and we further argue how important are the social and cultural perceptions of the natural assets for nature conservation, we also cite and define here a "Cultural Geology" counterpart for biology, especially since paleontology is a subdiscipline of both geology and biology. Despite the term "Cultural Biology" had already been used in Portuguese in a few Brazilian works (e.g., Dumas 2018; Rodrigues 2018; Codá 2018; Coelho and Da-Silva 2018a, b; Da-Silva 2018) and as part of the title and the main aim of a journal from Brazil ("A Bruxa: uma revista de biologia cultural"[1]), this concept was never formally defined. It is informally suggested cultural biology to be understood as the study of the presence of living beings in a plethora of cultural manifestations (personal observation), once it seems consonant with the formal established definitions of cultural entomology and cultural zoology (see below). However, this can be a restrictive vision for the term.

Therefore, it is proposed here the understanding of cultural biology as the scientific field responsible for assessing the importance, influence, and presence in different cultural manifestations of concepts, jargons, proverbs, and any objects (e.g., animals, plants, fungi, other organisms) that fall within the field of study of biology. We also include in it the use and allusions of literary works related to biological science, besides the portraying and reference of influential biologists, paleontologists, naturalists, or other people who made great contributions to the biology field. The examples below demonstrate references to terms (natural selection), concepts (anagenesis), and scientists (Charles Darwin and

[1] https://www.revistaabruxa.com/

Stephan J. Gould) intricately linked to biology. Although it does not constitute the presence of non-human organisms in the cultural manifestations, they should still be part of the study of cultural biology. Similar terms, "bioculture" and "biocultural," were first attributed to an unrelated concept: the combining use of human biological and cultural properties to adapt to an environment. For instance, Powell (1898), the first to use it, applied the term to explain that our species is not purely adapted to cold due to our biology (thick pelage), but due to combined action of human mind (biology) and learned behavior as the capability to invent shelters, clothes, and fire (culture). However, the term is problematic since it has been used later with contrasting meanings (Wiley and Cullin 2016).

Evolutionary concepts and terms, even when misunderstood, are frequent in popular culture, without any direct or indirect reference to non-human living beings. This phenomenon can be observed in Brazilian sports journalists, as it has been said that the Cuban wrestling Olympic training is considered "one of the greatest projects of natural selection and survival of the strongest that the world has ever seen (…)".[2] Despite being conceptually inappropriate to call this phenomenon under the name of natural selection, the use of the term shows the conspicuous influence in popular culture of the scientific studies about the moving mechanisms of evolution and the famous book written by Darwin (1859), albeit the notion of differential survival and tendency of fixation of favorable forms and deletion of unfavorable ones is already present in the writings of Empedocles (490–430 BC), almost 1500 years before the publishing of the British naturalist's book (Zirkle 1941).

Additionally, Charles Darwin is diversely represented in multiple artistic works, as the Disney animation Tarzan (1999). Similarly, paleontologist Stephan Jay Gould—who besides exercising a notable role in scientific popularization, also made major contributions to the extended evolutionary synthesis, especially by introducing the idea of punctuated equilibrium (Eldredge and Gould 1972)—had a special appearance in The Simpsons cartoon. The famous images, and its satires, of the linear and progressive human evolution (Fig. 2), although depicting a misrepresented view of the evolutionary history of our species, consists also in the presence of anagenetic evolutionary processes in culture and popular imaginary.

In King's (1974) novel, the author attempts to use jargon adopted by Genetics to explain Carrie's telekinesis, claiming that such a trait would be recessive for men and dominant for women. Another situation concerning the influence of heredity and genetics ideas are observed in The Lost World: Jurassic Park (1997) film, when the character Ian Malcolm states to antagonist Peter Ludlow that talent always skips one generation. Although such themes were observed long before biology was a formally recognized science—Aristotle, for example, preluded concepts of genetics such as genotype ("mover nature," or "nature as mover") and phenotype ("final nature," or "nature as end") as well as inheritance itself (Henry 2006)—the study of these phenomena is in close association with biology. Therefore, assessing its presence in different kinds of cultural manifestations must be the scope of cultural biology too.

The word and idea behind extinction can be present in many cultural expressions without necessarily being restricted to the end of one or multiple non-human lineages; it may portray the extinction process of our own species too. Accordingly, global warming and its meaning are addressed by different kinds of arts and, because it is a transdisciplinary theme, is also studied by biologists. The same occurs with concepts and even terminologies related to environmental education, conservation, sustainability, biochemistry (proteins, vitamins, carbohydrates, etc.), and immunology. Viruses are not consensually considered living beings but they are studied by virology, a biology, and medicine specialty. Viruses and the diseases transmitted by them, for example, are depicted in a plurality of artistic works as one can notice by the causal relationship between virus and zombification in the Resident Evil 1996-, franchise. Zoonoses may have their names and even symptoms portrayed in many cultural manifestations without the quotation or even the author's recognition of their biological vectors during the design of the work. The creationist documentary "Is Genesis History?" (2017) quotes "Nothing in the world makes sense except in the light of Genesis," a clear reference to the renowned sentence that makes up the title of Dobzhansky's (1973) classic paper: "Nothing in Biology makes sense except in the light of evolution." Accordingly, Herbert Spencer's (1820–1903) famous, though philosophically and conceptually problematic statement that natural selection would be the "Survival of the fittest" is also widely referenced in multiple artistic works, sometimes being adapted as in the case of the music album "Survival of the Fastest," of Gama Bomb band.

These examples would be included in the field of study of cultural biology *only* if we adopt this wide definition proposed here, in contrast to the more restrictive view which consider that this new branch of natural sciences would be exclusively dedicated to assess the presence, importance, and influence of non-human organisms in various cultural manifestations.

[2] https://www.youtube.com/watch?v=102qpKh2eX8

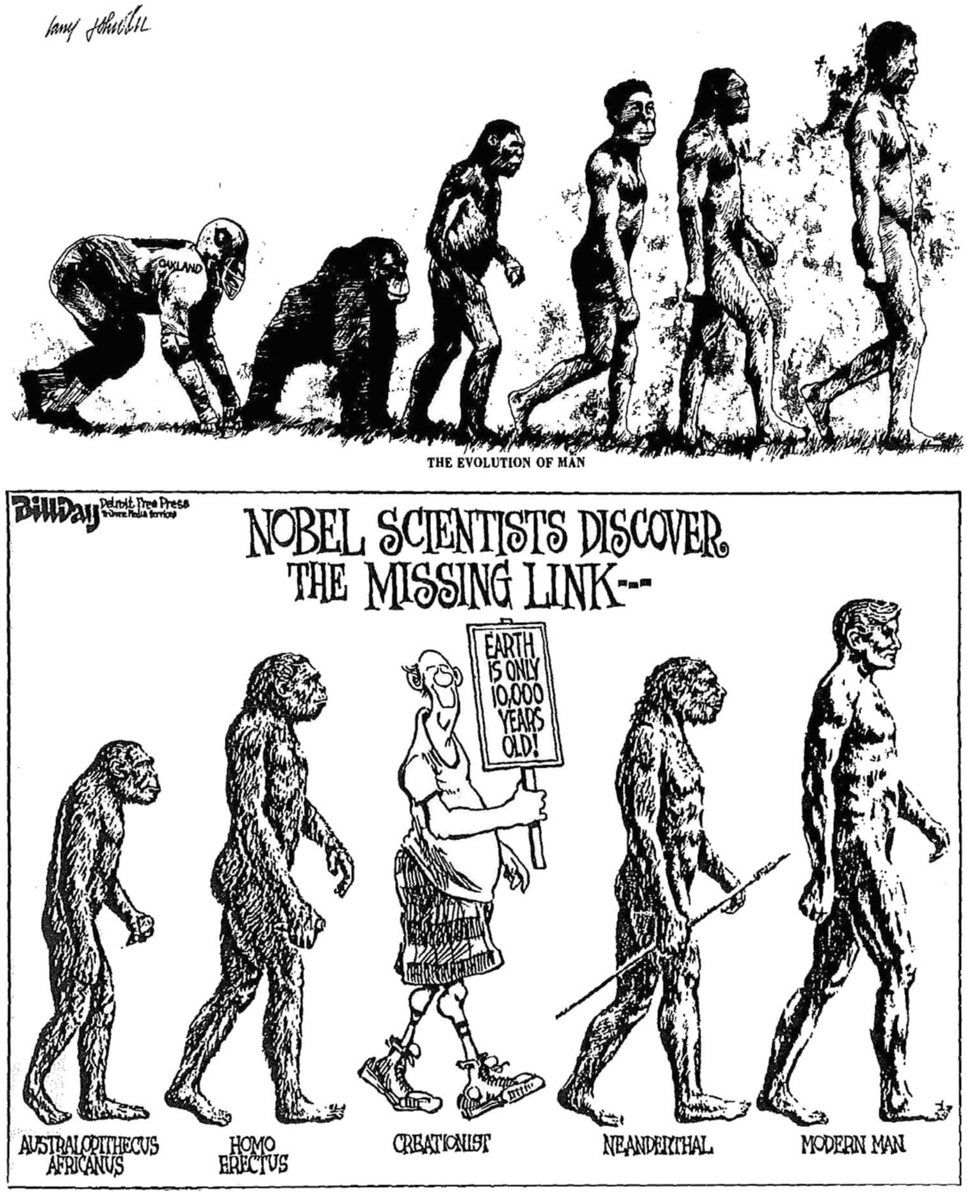


Fig. 2 Famous image of linear human evolution and its satires. Images edited from Gould (1989)

Cultural Zoology

The foundations of what is now recognized as cultural zoology originate back in the mid-1970s, in USA, when Hogue (1975, cited by Monserrat 2012) coins the term cultural entomology in literature. Later, he defines the concept as the study of the influence of insects in human cultural manifestations, listing one dozen of these expressions in which these animals could be represented somehow (Hogue 1980). This author acknowledged publications regarding what he called cultural entomology were already existent at the time, albeit they were scarce. Hogue (1980) also proposes "ethnoentomology" as more appropriate when referring to the assessment of entomological aspects seen in ancient societies. Here, we agree with Hogue (1987), considering the latter as part of cultural entomology.

In his text about the faunistic representation in the Mesopotamian culture, Monserrat (2012) referred several non-insect arthropods (e.g., crabs, myriapods, scorpions, spiders, lobsters) to what he called Mesopotamian entomology, what may indicate that his conception of cultural entomology might be broader. According to Da-Silva (pers. comm.), this view is not senseless since people can frequently call all arthropods as insects; thus, the cultural meaning of the word insect differs from the taxonomic one. The first cultural entomology colloquium occurred in 1984 (Hogue 1987). Despite this event and the formulation of a chapter focused on this thematic written for a

technical encyclopedia of insects (Hogue 2009), this field remains relatively unknown even among entomologists.

Da-Silva and Coelho (2016) defined cultural zoology as the study of zoological elements in the most diverse kinds of cultural manifestations. In a similar way, the cultural zoology is part of the cultural biology (Fig. 5). Here, it is proposed an extension. Similarly to cultural biology and cultural geology, cultural zoology should also assess the importance, influence, and representation of literary works relevant for zoology, in addition to people that contributed to the study and development of this field. Such influential individuals do not need necessarily to be academics. For instance, Brazilian Francisco Xavier Cardoso Caldeira,?-1810, former director of Casa de História Natural in Rio de Janeiro (first cabinet of natural history in Brazil and the possible precursor of Museu Nacional do Rio de Janeiro, the oldest scientific institution in Latin America), played a huge role in the development of Brazilian zoological knowledge. This artist, born in Santa Catarina, was responsible for collecting, delivering, conserving, and cataloging up to family level several Brazilian animal specimens sent to Portuguese museums. In addition, he dedicated himself to teach such proceedings to a few apprentices, being considered not only the pioneer of taxidermy in Brazil but the responsible for helping to spread this activity, with special emphasis to the future interim director of Museu Nacional do Rio de Janeiro, João de Deus Mattos (Absolon et al. 2018). More frequently represented in artistic manifestations, British Mary Anning also represents a non-academic person that greatly contributed for a specific zoology subfield, paleozoology (see below).

Cultural Paleontology

Cultural paleontology was first used by Astudillo (2010) as a new interdisciplinary research line characterized by the study of the sociocultural functions and utilities of fossils, focusing on culturally relevant paleontological elements, and their importance in human culture. He even incorporates the relationship between myths, legends, folk tales, and fossils under the study of cultural paleontology, but these associations will be commented on the next topic. Here, we also suggest cultural paleontology should study the presence and influence of literary works and paleontological concepts in cultural manifestations, besides people that greatly contributed to paleontology. We consider cultural paleontology a subdivision of both, cultural biology, and cultural geology (Fig. 5).

For instance, Mary Anning (1799–1847) is commonly represented in different art productions. "Cia. delas de Teatro," a Brazilian company composed solely by female actresses, recently promoted a play to tell part of Mary's personal story.[3] Mary was a young Englishwoman born in an extremely poor family in such a way she could never have access to formal education and, aside her brother, she was the only of her parents' nine children who managed to survive up to adulthood (Norman 1999). She subsidized herself through trading the fossils she collected on the cliffs near coastline. Mary made immeasurable discoveries, from belemnite cephalopods whose ink she had used to make her anatomical illustrations of the fossil organisms she encountered, to the first reasonably completed ichthyosaurs and plesiosaurs skeletons, besides being the first person to correctly interpret coprolites as fossilized feces (Tickell 1999; Clary and Wandersee 2006; Vincent et al. 2013). Mary's talent was so huge that despite never had attending school, she was able to learn French by her own, so she could read the leading publications of the time on geology, comparative anatomy, and paleontology. Also, she treated any paleontology authority as intellectually equal and many researchers claimed she knew more than anyone in the field, which led her to be known as "paleontology princess" in 1837 (Tickell 1999; Norman 1999). As some authors commented (e.g., Clary and Wandersee 2006) Mary Anning came to be represented in many international artistic works, becoming part of popular culture, an object of study of cultural paleontology as defined herein. Studying the cultural impact of important paleontologists may help to develop crucial geoturism and geoconservation strategies.

According to Astudillo (2010), paleontology may be present in different types of cultural manifestations: cooking, literature, myths, legends, religion, paintings, illustrations, sculptures, ornaments, toys, board games, etc. Nowadays, paleontological elements have obtain much (if not most) of their cultural significance by their presence in audiovisual productions. Jurassic Park film was a great phenomenon, whose iconographic influence in theropods is very obvious. Traditionally represented in books, old movies, and cartoons as bipedal beings with a tendency to an erect posture while their tails touch the ground (this image was even described in the original book written by Crichton (1990), which inspired the cinematographic version), after this movie, a generalized tendency in depicting carnivore dinosaurs bearing a horizontal trunk (a more scientifically accurate representation) spread, at least regarding books and movies (Ross et al. 2013) (Fig. 3). The influence of the 1993 Jurassic Park film can also be noticed in the almost ubiquitous representation of theropods porting highly pronated hands after the film success (Fig. 3). This anatomical condition is present in the film but do not have any scientific support (Milner et al. 2009). This inaccurately pronated fore autopodia is

[3] https://www.facebook.com/culturainglesasp/videos/cultura-inglesa-festival/10155349400132601

Fig. 3 Comparison between distinct theropod dinosaur illustrations. **A**—Outdated ichnography of a *Tyrannosaurus rex*, with a more upright posture and tail touching the ground for body support; **B**—*T. rex* reconstruction in Jurassic Park film, with a more horizontal trunk and erroneously pronated hands; **C**—Godzilla character in its original design, presenting an instance similar to outdated *T. rex* depictions, showing few alterations between 1954 and 1995; **D**—1998's Godzilla design, its first version totally idealized after Jurassic Park movie, showing a horizontal trunk and pronated hands. Pictures retrieved from Google Images website

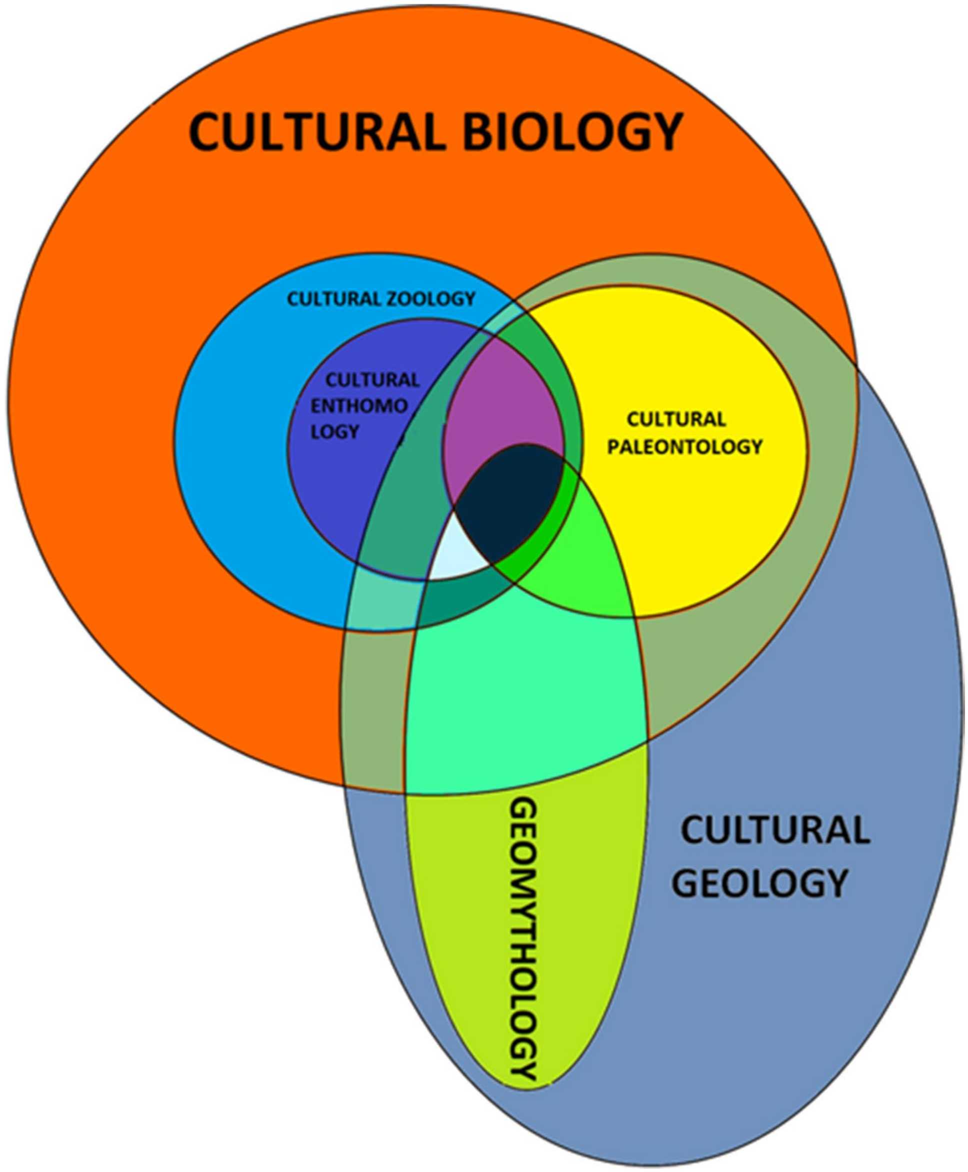
Fig. 4 Two memes that circulated through paleontological community on social networks. Images retrieved from Facebook group "Paleontology Coprolite-posting"

seen even in documentaries reconstructions, which supposedly should be based solely on scientific data. This franchise recently developed a short movie, Battle at Big Rock (2019),[4] in which the hands of a theropod (an *Allosaurus*) were represented in the right position (medially-facing palms) for the first time since its 1993 debut, generating a big commotion into the paleontological community, which positively reacted through memes on social media (Fig. 4).

The first Jurassic Park movie also universalized a select number of dinosaur genera in global popular culture, notable in the case of the Crichton's (2018) posthumous novel cover, in which there is a *Tyrannosaurus* skull probably present there for mere commercial appeal, since this genus is not present in

[4] https://www.youtube.com/watch?v=C7kbVvpOGdQ

Fig. 5 Relationships between cultural biology, cultural geology, cultural enthomology, cultural zoology, cultural paleontology, and geomythology. Diagrams and intersections sizes do not correspond to the real proportionality of the area of knowledge that is contained in the diagrams



the book's plot because it was not even discovered at the time the narrative takes place. Dinosaur movies have a big influence in popular culture. Duarte et al. (2016) noticed 31.1% of 399 elementary and high school students from Rio de Janeiro claimed humans and non-avian dinosaurs coexisted at some point of Earth's history. These authors suggested an influence of the movies. Although we agree, we also believe in the additional effect of a religious background and poor science education impact, as explanation for these terrible results obtained.

Geomythology

Vitaliano (1968), inspired by the word *euhemerism* (the idea that certain deities would be based on real characters and historical events), created the term geomythology, a neologism regarding the application of this notion to geodiversity, being defined as the interdisciplinary study of the relationship between myths/legends and real geologic events that inspired them. Considering her definition and examples, generally associated with tectonic events and their consequences, preliminarily they do not encompass paleontological elements.

However, such elements have been receiving increasing attention in geomythological studies, including correlating fossil footprints and other fossil traces with myths (Mayor and Sarjeant 2001). This tendency is very conspicuous here in Brazil. Some examples are as follows: (1) Fernandes (2005) makes a general overview about the relationship between fossils, myths, and folklore (based on previous foreign literature), suggesting the inclusion of paleontological elements within the field of study of geomythology; (2)

Ponciano (2015) consists in the first paper that analyzes myths from Brazil under a geomythological perspective, addressing the paleontological elements in Mapinguari, Cobra-Grande ("Big Snake"), Macunaíma and the origin of Roraima Mount legends, from Northern Brazil; (3) Velden (2016) also discourses on Amazon monster Mapinguari, commenting that its image is said to be based on extinct ground sloths, as Ponciano (2015) already documented; (4) Santos et al. (2016) relate Mapinguari depiction to putative findings of ground sloth fossil remains by native people, or to the encounter of humans and these animals when they were still alive; (5) Caetano and Ponciano (2018) recognized griffin traces in the fictional character Trico from The Last Guardian (2016) video game, commenting on Mayor and Heaney's (1993) and Mayor's (2000) correlation between ceratopsian dinosaur fossils and this mythological Greek creature; (6) Souto and Neves (2018) relate Jurassic mammals pentadactyl footprints (*Brasilichnium elusivum*) found in Araraquara municipality (São Paulo) to Curupira Brazilian folklore; (7) Ponciano (2018) summarizes how she idealized *GeoTales*, a research group active since 2015, dedicated to popularize geosciences through artistic performances, including a geomythological approach in several cases; (8) Nunn and Ponciano (2019) indicate many similarities in the oral (and visual) records associated with paleontological elements in Australia and Brazil. They correlate these similarities with the nature of Australian and South American megafauna and their geological context, particularly in drier parts of these continents, where certain megafauna were more common, owing to the lack of dense vegetation.

However, the oldest Brazilian published document that contains a primeval geomythological study consists of a book written by the priest and geographer Casal (1817, p. 44) in which he hypothesizes that fossil proboscideans might correspond to the biblical creature Behemoth, in a clear causal correlation between geodiversity elements and mythology, corresponding to a geomythological analysis (see also Fernandes et al. 2013 for additional commentaries on Casal 1817).

Mayor and Sarjeant (2001) also address some Brazilian geomyths related to ichnofossils, highlighting the footprints called by the population of "footsteps of a saint" near Cianorte municipality (State of Paraná). Although those authors did not identify large footprints in those localities, Cianorte is only about 56 km from Cruzeiro do Oeste, a municipality where there are reported findings of the supposed functional monodactyl theropod dinosaur *Vespersaurus paranaensis* (Langer et al. 2019; Kellner et al. 2019). In late 1970s, Leonardi (1977) described several footprints from Córrego Creek site, in Cianorte. He highlighted a remarkable set for being hard to interpret as its digits traces were not clear, finally suggesting it was produced by a bipedal animal, possibly a coelurosaur dinosaur. Later, Leonardi (1994) maintained his view that these were coelurosaurian footprints but added the interpretation they were of functionally monodactyl ones. Langer et al. (2019) suggested these footprints pertained to *Vespersaurus* (which is an abelisaur rather than a coelurosaur) or to some close relative. Although these 8 cm monodactyl footprints certainly could be mistaken for young angels' boots or shoes by local residents, other more elongated hind autopodia marks (CICC2, CICC3) from the same locality fit better what we would expect from a "footstep of a saint" impression. These were initially suggested as produced by small quadruped therapsids (Leonardi 1977), and then as *Brasilichnium elusivum* mammalian ichnospecies (Leonardi 1994) (also assigned to Curupira legend according to Souto and Neves 2018), albeit those present a clearly distinct morphotype from other specimens also assigned to *B. elusivum* (CICC5, CICC6) by Leonardi (1994).

Therefore, the scientific literature regarding studies of Brazilian geomyths tends to have a very paleontological bias. Probably the two most influential works on the correlation between myths and fossils refer to the Mayor and Heaney's (1993) paper and mainly to Mayor's (2000) book. Mayor (2000, p. 194) even states that within the geomythological concept, it "would also apply to lore about conspicuous prehistoric fossils," formally introducing the study of the interrelationships between paleontological elements and myths under the scope of the field defined by Vitaliano (1968).

Geomythology is very peculiar regarding how it relates to the other concepts covered in the topics above. It always involves the influence of geodiversity elements on human culture, being considered here part of the wider area of cultural geology. However, its relationships with cultural biology, paleontology, and zoology are more intricate. For instance, a portion of it is completely suitable as a subdivision of cultural paleontology, as in cases when planispiral ammonite shells were related to Greek god Amon's horns and petrified snakes beheaded by Saint Hilda (Fernandes 2005 and references therein), or the possible Mapinguari legend inspiration in extinct ground sloths (Ponciano 2015; Velden 2016). However, geomythology could also comprise cases that are perfect examples of cultural biology and zoology but not necessarily connected to cultural paleontology, as the Cobra-grande (Ponciano 2015), Devil's Tower, and Kashima-no-kami (Vitaliano 2007) myths. These involve depictions of animals (a snake, a bear, and a catfish, respectively), and are related to geodiversity through tectonic events and their consequences, but there is no strong hint to assume they have an inspiration in paleontological elements. Similarly, geomythology could sometimes not be related to cultural biology, when myths are based only on geologic events. It is the case of volcanic eruptions in Santorini, which would have unleashed large tsunamis and inspired

Greek legends about gigantic floods and continents disappearance, including perhaps the case of Atlantis (albeit certain inconsistencies with scientific data regarding the dating of the event suggest the improbability of this relationship) (Vitaliano 1968, 2007).

Therefore, it is here considered that geomythology could be divided into three portions: (i) one which intersects with cultural paleontology; (ii) the second intersects with cultural biology but not with cultural paleontology; (iii) and the last one does not present any relationship with cultural biology. These relationships between all the concepts covered here up to this point can be seen in Fig. 5.

Cultural Taxonomy

The oldest known report of it comes from Coelho and Da-Silva (2018a). Cultural taxonomy lacks a formal definition too. It is defined herein as the scientific field that seeks recognizing the identity of characters represented in cultural manifestations, aiming to reach the least possible inclusive operational taxonomic units (OTUs) that may have inspired them (or to which they resemble most), using as recognition criteria the comparison and description of the morphological, ethological, physiological, and/or ichnological characters concerning the object identified as cultural product and its possible sources of inspiration. We also recognize the inclusion of ecological, historical, and biogeographical data, when is possible to perform an analysis of this nature.

Evidently, most of the scientific works that (at least partially) address on what we call biopolitistics analysis (derived from Greek, βίος – bios, "life;" πολιτιστικός – politistikós, "cultural;" i.e., referent to cultural biology and its subdivisions) will require the authors to make some degree of identification of the represented organisms identity, when it is the case of living beings being present in any way. However, we only consider as a work of (or using the) cultural taxonomy those that present, as defined above, a description and comparison of observable features between the represented entity and the organisms from which it was inspired or resembles most. A study merely claiming a character was based on a given biological group without giving any further justification for such a position; however, conspicuous this inspiration may be, should not be considered a cultural taxonomy research. The detailing degree and the utilization of more specific anatomical terms will vary according to the scope of the authors and the quantity of information available that can be extracted from the depiction, so the analysis may or may not be simplified.

Examples of cultural taxonomy works, as here defined, focused on paleontology can be seen in Mayor and Heaney (1993), Mayor (2000), and Agnesi et al. (2007), which also make a historical background and prove the longevity of this line of research, with at least centuries, despite its obscurity. More recent works regarding this newly defined field can be seen in Caetano and Ponciano (2018) and Caetano et al. (2018). In the former, we morphologically assessed the creature Trico, from the electronic game The Last Guardian, and identified several traces referable to extant (domestic cats, dogs, giraffes, emus, fennec foxes, caracals, lions, cheetahs, etc.) and extinct animals. Among fossil representatives, we noticed an indirect relationship to ceratopsian genus *Protoceratops*, due to the creature clearly be based on a griffin, which in turn is based on Mongolian ceratopsians (Mayor and Heaney 1993; Mayor 2000). Caetano and Ponciano (2018) also noticed a morphological resemblance of Trico's horns and those of allokotosaur *Shringasaurus indicus*, albeit this fictional character could not be inspired in this species once the game launch preceded the publishing of the work describing *Shringasaurus* (Sengupta et al. 2017). Caetano et al. (2018) compare the antagonist Cretaceous from Ice Age: The Meltdown (2006) film to two extinct taxa: Ichthyosauria (to which it was officially assigned) and Metriorhynchidae, utilizing as criteria both morphological and behavioral characters. We concluded that the identity of the film character is more in line with the latter, once it shares more unique characters with it (7 characteristics shared *only* with Metriorhynchidae × 3 shared *only* with Ichthyosauria); in addition, we comment on homoplasies as resulting from positive selection favoring their piscivory and swimming habits.

Emergent Strategies to Promote Geoconservation

We expect to demonstrate how these fields associated with the cultural values and perceptions of nature can provide a better way of achieving the desired results in geoconservation, comprising a more comprehensive vision by adopting the geoheritage wider definition of Ponciano et al. (2011). To reveal it, we formally defined and discussed three new, emerging, and already applied fields of natural sciences (cultural geology, cultural biology, and cultural taxonomy), and discussed cultural paleontology, cultural zoology (designated before by other authors and modified here), and geomythology. When applied together with other geoconservation strategies, these cultural-related fields can successfully protect geoheritage from a broader array of hazards, as we will debate now. Finally, in the next topic, we propose that very influential geomyths and geodiversity-centered audiovisual products should be encompassed within an intangible geoheritage category, as a Ponciano et al.'s (2011) ex situ geological heritage subset.

Although presenting multiple definitions, geoheritage generally is a status given for a geodiversity element

considered of exceptional value. Being aware conserving all geological features in the world is impossible, geoscientists try to recognize and infer which ones are the most relevant, to foster strategies and prevent their destruction. Brilha (2005) considered geoheritage the set of geosites with at least one geodiversity component with exceptional scientific, educational, cultural, or any other value. This definition is more centered on geographically delimited areas rather than the objects themselves; therefore, excluding important minerals, rocks, and fossils that were displaced from their original site, as the museum collections. This view concerning geoconservation focused on geosites seems to be dominant at that time, as one might see in the historical review of Brocx and Semeniuk (2007). In Brazil, for instance, there are three volumes of a national book completely dedicated to emphasize the importance of the most relevant Brazilian geosites in order to foment their inclusion in the UNESCO's list of World Heritage under the geoheritage category (Schobbenhaus et al. 2002; Winge et al. 2009; Winge et al. 2013). Few examples, as Uceda (1996) and Hussain et al (2008), included geological collections in the geoheritage definition, the latter even distinguishing between geoheritage sites and geoheritage resources (geodiversity elements whether in situ or ex situ).Thus, as expected, the focus of geoconservation approaches is still predominant on in situ geodiversity elements.

Ponciano et al. (2011) publish a quite different and wider interpretation of what they considered as geological heritage, subdividing their definition into two distinct categories: in situ and ex situ geoheritage. The former would be a *synonym* of Brilha's (2005), whereas the latter encompasses geodiversity specimens which possess any kind of exceptional value (cultural, scientific, esthetic, etc.) and were removed from their site of origin and housed in scientific collections. Ponciano et al. (2011) also considered as ex situ geoheritage references related to the notable geodiversity element itself and to its assessment, collecting and keeping processes, such as published and unpublished scientific documents (papers, books, dissertations) and data (photographs, maps, illustrations, personal letters, movies, field notebooks, etc.), reproductions (sculptures, paintings), and reconstitutions (biomechanical, paleoecological, paleogeographic, and biogeographic models), besides old laboratories and obsolete instruments previously used for studying geodiversity, maintaining the exceptional value as criterion. They also discuss the advantages and disadvantages regarding the conservation of ex situ and in situ geoheritage.

Posteriously, Vilas-Boas et al. (2013) trailed a similar idea for the ex situ geoheritage definition, at least for scientific paleontological collections, acknowledging their scientific as well as educational and touristic significance. Later, Brilha (2016) changed his previous 2005 definition, including in some way the ex situ geological heritage. The main (and fundamental) differences between Brilha (2016) and Ponciano et al. (2011) proposals are that Brilha (2016) only considered geoheritage those geodiversity elements with high scientific value, and he does not include the references to such elements (e.g., books, papers, letters, photographs, monographs, maps, etc.) within his proposal of ex situ geoheritage. Focus solely on the scientific value when determining if an object should be recognized as geoheritage is a very conservative proposal, in relation to the majority of the previous definitions (Brocx and Semeniuk 2007), and is not widely accepted (Brilha 2018). Later, Brilha (2018) admitted that "sites that were relevant for the history of geosciences at the national and international levels may also be considered to have scientific value." Still, this segregation of the scientific value is intrinsically harmful (making people believe scientifically valuable geodiversity elements are more relevant than esthetically/culturally/educationally significant ones), and could trigger important consequences to geoconservation, leading to worse results, which we argue further in this paper. Now, we will focus on criticizing the exclusion from the ex situ geoheritage definition of the different types of references (e.g., correspondences) to important sets of rocks, minerals, fossils, and landscapes. But first is necessary to briefly discuss the importance of including ex situ collections in geoheritage since some authors may avoid to do it for some reasons (Lima and Carvalho 2020).

It is valid to start with the "Rio de Janeiro Charter" (Carta do Rio de Janeiro), idealized in the 4th International Material Culture and Science and Techonology Heritage Seminar (in 2017), which besides recognizing scientific collections cultural heritage significance, it also proposed the inclusion of scientific places/facilities (laboratories, zoos, museum, etc.), scientific collections and instruments, field notebooks, scientific pictures, books, and documents under Brazilian cultural heritage category (Viana and Carvalho 2019). Despite mostly focused on the cultural relevance of those objects, this definition is more aligned with the ex situ geoheritage concept of Ponciano et al. (2011), wider and older than the proposal of Brilha's (2016). Further, according to Viana and Carvalho (2019), during a Brazilian Geological Congress in 2006, the geoscientists signed the Aracaju Declaration, recognizing museum collections as geoheritage.

One of the motifs to not include the elements safeguarded in scientific collections under the geological heritage classification used to be that those "samples if encountered in public museums, they are automatically protected from deterioration by natural processes and loss by theft, vandalism, etc." (Brilha 2005, p. 55). However, besides taking into consideration disappearances of scientific collections components in public museums (e.g., see *Agialopus* holotype comments in Milner et al. 2009), the safety of those materials is also very threatened by limited financial resources provided by government, especially in developing countries. For instance,

recently (September 2018) the Museu Nacional do Rio de Janeiro (Natural History Museum of Rio de Janeiro, Brazil) had undergone a fire incident that destroyed most of its collections. This tragedy caused the loss of many types of knowledge, and affected a collection of almost 60,000 fossils (Pássaro et al. 2014). Their post-fire status is yet mostly unknown. The majority of them (35,423 fossils; > 59%) was collected during late 1800s and included rare specimens of the practically unknown Brazilian Paleozoic Amazon paleontology (Fernandes et al. 2007). Additionally, the fire was also likely responsible for extant biodiversity loss, as Kury et al. (2018) claim a yet undescribed new species of amblypygi *Charinus*, which lived exclusively in pluvial galleries of the museum, was probably extinct. One of the main reasons of this fire is the chronic lack of government support (Zamudio et al. 2018), increasing the vulnerability of the building for pest infestation (what in fact happened 1 year before the fire; see Ribeiro 2018) and the occurrence of smaller fires. These problems in the infrastructure of the building are reported at least since the late 1980s (Carvalho 1988).

For other reasons, two Brazilian public scientific institutions (Fundação Zoobotânica, and Museu dos Fósseis) had recently been closed and the destiny of their fossil specimens is yet unknown (Viana and Carvalho 2019). Furthermore, in a Museu Nacional's unpublished institutional document, the deceased Brazilian paleomastozoologist Carlos de Paula Couto reports that technicians mistreated a ground sloth skull, leaving the fossil on the ground of a hallway where people frequently transited (Rodrigues 2017). Ponciano et al. (2011) point out the extraction of geological materials from their original site in order to "keep them safe" in scientific collections can also cause some destruction or modification in the samples, due to post-collection transportation process. In fact, the fragmentation degree may even increase due to the transportation of fossils from the original site to the collections and may be accounted during taphonomic analysis (Flessa et al. 1992). Additionally, geodiversity elements housed in public scientific institutions may also be discarded before undergoing a suitable assessment, due to lack of room for new specimens (Ponciano et al. 2011). Therefore, the statement that geodiversity materials are safe in museum collections does not seem to reflect the reality of at least a portion of public scientific institutions worldwide.

Unpublished documents can be historically and culturally significant, as many of those studied by Rodrigues (2017), which register how geology and paleontology-centered exhibitions of Museu Nacional evolved through almost 200 years, and some might have an exceptional scientific value too. For instance, Kenneth Caster's field notebooks and personal correspondences have historical, educational, and scientific value, as their assessment provided information on a previously unknown fossil-bearing outcrop and on new fossiliferous levels in various sites (both in northeastern Brazil), besides helping to track down a yet poorly studied fossil collection ("Caster Collection") repatriated to Brazil due to a request made by Luiza Ponciano to the Geology Department of the University of Cincinnati in 2012. Before this, the Caster's Collection was considered missing, and the only local records in Brazil indicated that the fossils should be housed in the Museu de Ciências da Terra (Rio de Janeiro). The mystery was solved by Luiza Ponciano when she decided to look for records of the Brazilian fossils in the documents left by Kenneth Caster in his office since 1992. In 2016, the fossils arrived in Brazil (Lima and Ponciano 2017). At least about half of this collection is still safely housed in the remaining buildings of the Museu Nacional institution that were undamaged by the 2018 fire.

Similarly, analyzing Brazilian paleontologist José Henrique Gonçalves de Melo's field notebooks and photographs, Ponciano et al. (2012) discover and describe unexplored fossiliferous sites referred to Devonian of Brazil. A letter written in 1800 by Brazilian naturalist João da Sylva Feijoo reporting findings of fossiliferous nodules containing well preserved fossil actinopterygians and amphibians from northeastern Brazil, allowed Antunes et al. (2005) to encounter five *Vinctifer comptoni* fossil specimens in "Academia das Ciências de Lisboa" museum (Lisbon). These *Vinctifer* specimens bear historical significance as they are the oldest known fossil collection from Brazil, therefore, giving Feijoo's letter importance as one of the earliest written reports of fossil findings in the country. However, the letter might also have a great scientific significance because it refers to fossil lissamphibians from the same locality, albeit unfortunately these specimens whereabouts are not determined yet (Antunes et al. 2005). Considering anuran fossils, despite being diverse, are relatively uncommon in those outcrops (Báez et al. 2009; Carvalho et al. 2019; Agnolín et al. 2020; Moura et al. 2021), Feijoo's specimens and his letter might provide great contributions to science, including recognition of putative new species.

According to Masse et al. (2007), "the segregation of knowledge hinders our attempts to understand past holistic societies", but we can still see this over segregation being applied to valuable geodiversity elements nowadays. The same authors also state that "traditional cultures were/are largely holistic" and they "do not normally segment their natural universe, society, and knowledge systems into separate and independent components". In their opinion, "this contrasts with modern western society," where "sciences are divided in many individual disciplines, which in turn are divided into sub disciplines".

Integrating culture and science through cultural geology and cultural biology (especially cultural paleontology and taxonomy) can improve the geoconservation strategies, and now we will propose some ways to settle these ideas.

Depending on how one uses these new fields, they can generate many types of affective memories associated with a deeper and closer perception of the geological features (geoaffective memory) on people to whom geosciences are being disseminated. Thus, avoiding the segregation between the many types of values used to evaluate the geodiversity as geoheritage (in addition to also be considered as cultural and natural heritage, as an integral heritage) can help to build a bridge linking the popular and the scientific knowledges (based on the development of a closer familiarity with more bio/geodiversity elements).

One of the most efficient ways to protect a heritage is to make local people aware of its relevance and the required conservation measures, besides stimulating the general interest in science. Several methodologies may be used to disseminate the importance of geodiversity elements as well as their influence in society: lectures in educational institutions and other public settings (Ponciano 2013; Caputo and Ponciano 2013; Mendonça and Valois 2017), tourism (Pãozinho and Ponciano 2019), preparation of basic education levels classes centered in geological themes, taught by competent professionals (Barbosa 2003; Compiani 2005), dynamic museum exhibitions containing playful activities which stimulate creativity and participation (e.g., Castro et al. 2011; Vieira et al. 2007; Faria et al. 2007), use of arts to arouse the interest and/or affective memory for geodiversity elements (see Henriques et al. 2008, 2010; Santos et al. 2016, 2017; Santos and Ponciano 2017, 2018; Ponciano et al. 2017; Ponciano 2018; Caetano and Ponciano 2018; Caetano et al. 2018), prospecting recreational activities in the classroom and in non-traditional educational spaces (Dotto and Ziemann 2015; Neves et al. 2008; Garcia et al. 2014; Faria et al. 2007; Vieira et al. 2007), and the visitation of geologically interest places (Travassos and Travassos 2005; Mendonça and Valois 2017).

Community engagement already proved to be efficient in biodiversity conservation, as the case of the Ilha Grande Bay residents, which helped to remove thousands of *Tubastraea* spp. coralla, an invasive species (Creed et al. 2017). They also used the skeletons to make handicraft, aiming the tourists. According to Pãozinho and Ponciano (2019), the direct or indirect involvement of the population is essential to promote geoconservation strategies, a process they call "community empowerment in Geotourism" (deriving from a social design concept), which can be applied to geoconservation as a whole and to geohazards prevention as well (Mendonça and Valois 2017). According to Duarte et al. (2016), students whose schools were in a greater proximity to universities and extension programs (including scientific popularization projects) tended to manifest a better knowledge on paleontology and geology. Hence, an effective and respectful "scientist-population"/ "geoscientist-other scientists" communication must take place, integrating the local public (here also included academics who do not realize geodiversity importance) with the geosciences.

People's view of a scientist is stereotypical (male, Caucasian, wise, workaholic, dedicated, experimental researcher, an indoors worker, etc.) and does not correspond to the characteristics of most citizens, what lead many to believe their personality, gender, social class, or ethnicity are incompatible with those of a scientist (Chambers 1983; Rubin et al. 2003; Diekman et al. 2010; Heilman and Wallen 2010; Miller et al. 2015; Hazari et al. 2013; Godec 2018), moving them away from science. However, once people become aware their popular knowledge may be informative and useful for scientific progress; they can take an active role in the construction of scientific knowledge and develop a science identity (Popa et al. 2017). For instance, native people Karitiana have long reported the existence of a distinct kind of tapir in their Amazon living territory, but naturalists and scientists always neglect their claims. However, skulls collected by them, in addition to museum samples, led to recognition of *Tapirus kabomani*, the first newly described extant tapir species within 144 years (Cozzuol et al. 2013), albeit of disputed taxonomic status (Voss et al. 2014; Ruiz-García et al. 2016). Nevertheless, it shows natives' aptitude to notice a distinct population which could be considered at least a subspecies, in order to retain specific name. This is a clear example of popular knowledge and the active role (by reporting and collecting skulls specimens) of traditional people can lead to relevant scientific discoveries and discussions, bearing a significant potential for developing a widespread science identity.

Since Classical period, the word "myth" or *mythos* have been pejoratively used by some people like Plato, Thucydides, and Herodotus, which consider those as unrealistic, silly, and false (Masse et al. 2007). Oren (1993) accounts Amazonian residents believed indigenous Mapinguari myth is merely fantasious because it consists of a legend and they did not obtain empirical evidence in favor of this creature existence, despite the hints pointing to its foundations in real past animals. In his work about Mapinguari and the Brazilian natives Karitiana (who believe this creature exists), Velden (2016) states "the interpretations which treat Mapinguari on one hand as a legend, belief, myth (according to common sense) or folk tale, or on the other hand, as evidence for a scientific hypothesis, they both violate the ontological status of this being for Karitiana, overlooking and denying the experiential reality inhabited by these people, when exposes it as folkloric, false, literary, or superstitious, or reducing it to a misguided expression of an object of knowledge (…)" (our translation). He also opposes this trend in science that interpreted tales as mere fantasies (not being worth of scientific attention), neglecting their potential to provide valuable historical (and cultural) interpretations of reality (Masse et al. 2007; Mayor 2011). This trend generate a misleading

impression that scientific interpretation is better, superior to other supposedly inferior ways to interpret the world, such as the traditional knowledges (Masse et al. 2007). However, the educational use (also applied to geoconservation) of these traditional narratives does not depend on undoubted proof of empirical evidences or hypotheses that have been raised on these myths (Ponciano 2015; Popa et al. 2017).

Many (geo)myths present highly accurate descriptions of reality (Masse et al. 2007; Shanklin 2007) and certainly deserve attention, including from geoscientists. For instance, Hodgson (2007) demonstrates how Wintu California natives, by means of myths, precisely acknowledged a magmatic origin for obsidian, even pointing out to how quickly it occurs. Considering myths are present in people's everyday lives (being culturally significant and also provoke identity), they are prime geoconservation-driver strategies (Motta and Motta 2007; Kirchner and Kubalíková 2015). Indeed, a previous cultural bond of locals with some geodiversity elements through myths may grant community support for GeoParks even if they do not provide great economic benefits in a shortime scale (Popa et al. 2017). Hence, including geomyths (and other elements born from confluence between culture and geodiversity) into geoheritage category is an efficient manner for making local public identify itself with geology and recognize that the cultural knowledge, arts, and (geo)sciences are able to intersect. This contrasts with Brilha's (2016) proposition, which excludes geomyths from the geological heritage because they do not necessarily bear a scientific value (at least not under a more traditional view of science) neither are physical geodiversity elements. Capturing the attention of the general public to geological heritage concept through this inclusion of relevant geological-related cultural products (geomyths and dinosaur movies, for instance) into the geoheritage can make people more likely to pay attention to other geoheritage components that bear only scientific value, introducing them also into the popular knowledge and potentially giving them a cultural significance too.

If we keep this conservative view of considering the myths associated with geological elements solely under a "Cultural Heritage" classification, most people may not perceive their relationships with the geosciences, due the absence of a "geo" prefix. In fact, both prefixes and suffixes may influence on people's notion about a concept: people might think of geology as a geography sub discipline due to the shared "geo" (Duarte et al. 2016) and names ending in "-saur" or "-saurus" (*Lystrosaurus* and pterosaur) are generally associated with dinosaurs by non-academics. If one does not believe a prefix is important or can change people's perception of geodiversity assets, just imagine abandoning the terms "geoheritage," "geopark", and "geosite" for simply call them "natural heritage," "natural park", or "natural site". Assuming this, do not encompassing culturally, educationally or any other valuable "non-scientific" important geological feature into the geoheritage class is similar to excluding conservation paleobiology of the conservation biology field, which according to Dietl (2016), must lead to marginalization and closed discussions limited to paleobiologists, weakening it.

The intangible Geoheritage Category

Returning to Masse et al. (2007) reflection of the over segregation ubiquitously present in science and how these non-inclusive scientific approaches hinder our understanding of past societies, here, we also argue how they obstruct our understanding of the current societies as well. And this certainly affects geoconservation, as we extensively discussed above. At this point, we believe it is clear how essential is allowing cultural, historical, educational, and other values attributed to exceptional geodiversity elements to be accepted within the geoheritage. There is also a unique characteristic of the definition proposed by Ponciano et al. (2011) that must be considered: unnecessity of being limited to a physical object or space. When those authors introduce the term "ex situ geological heritage," they also encompass reports, records and any other kind of reference to geological features, elements, or geosites. Their proposal opens the door for inclusion of culturally influential geology-related cultural expressions into the ex situ geoheritage category.

Up to our knowledge, first usage of the term "intangible geoheritage" corresponds to Hussain et al. (2008) and denoted "the geological history and the prevailing geological process" of geological sites (e.g., coastal erosion process). They differ it from "tangible geoheritage", that is, the excepcional products from the geological processes. Thus, contrary to UNESCO's (2003) intangible cultural heritage, this definition does not relate to cultural assets. Later, Popa et al. (2017) defined the term as "the story that the (geo)site communicates through its fossils, minerals, textures, and structures, it is the moment in the Earth's history that it represents and the past events that it records", apparently being derived from UNESCO's proposal. Thereby, their definition probably encompass geomyths, events, practices, etc. associated to geodiversity elements from specific geosites. This would not include, for instance, intangible cultural products (e.g., movies, games) related to geodiversity elements in general terms. Unpublished document of Interreg Danube Transnational Programme (2018) also used the term "intangible geoheritage" in a cultural context, but it was loosely defined. Here, we broaden the concept of intangible geoheritage, and makes it an ex situ geoheritage subset of Ponciano et al. (2011). It encompasses all intangible cultural expressions relevant for humanity or a given population with a strong relationship to the geodiversity, as myths, legends, movies,

festivals, beliefs, etc. For example, a classic movie which influenced and still influences several generations (therefore culturally valuable) with insignificant or unimportant participation of geological features or elements should not be classified as an intangible geoheritage, because the geodiversity components must bear a significant role in the cultural product to fall within this newly redefined subset.

The interpretation of griffin mythology origin tracing back to ceratopsian fossils from Asia (Mayor and Heaney 1993; Mayor 2000), although few geoscientists disagree (e.g., Witton 2016), is highly accepted among geomythologists, being considered a landmark moment, leading to geomythology explosion in popularity within scientific community (Mayor 2011). This geomyth bears a highly cultural and scientific value, once the recognition of the griffin legend roots is a significant discovery for this field, being a classical example of how non-scientific interpretations of our world made by ancient people may provide precise information on reality. The griffin myth is a cultural phenomenon since its first unquestionable records in Greece, millennia ago, maintaining its relevance up to our century if one considers the depiction of this mythological animal in several recent artistic works. That alone would be enough to fit it into the intangible geoheritage category, but one aspect makes this geomyth even more relevant: Mayor and Heaney (1993) hypothesis for the origin of griffin mythology has inspired and being cited by children's books, novels, documentaries, museum exhibitions, technical textbooks, etc. (Mayor 2011). Therefore, nowadays, the acknowledgement of a ceratopsian inspiration for the griffin myth is beyond the scientific community, being already part of popular knowledge too, as she recognizes when citing the letters received from kids. Being aware of this, we propose such a landmark geomyth to be recognized under the intangible geoheritage class.

Since 1800s some naturalists, as the Argentinian Florentino Ameghino, proposed the association between the tales told by Native Americans about large creatures and the ground sloth encounters (Velden 2016). These assumptions would have made Mapinguari legend (Nunn and Ponciano 2019) an evidence that Brazilian natives had lived with those animals long before science found strong evidence to support they both coexisted (Piló and Neves 2003; Neves and Piló 2003) and interacted (Dantas et al. 2014) in Brazil. Furthermore, considering many scientists in fact believe Mapinguari myth has its roots in ground sloths fossils findings by Brazilian natives or human encounters with these animals when they were still alive (Oren 1993; Ponciano 2015; Velden 2016; Santos et al 2016), we propose this geomyth to be the second element incorporated here under the intangible geoheritage category. However, according to Vegini and Vegini (2015), there are relatively very few published works concerning Mapinguari-ground sloths correlation, since most of the works approaching this creature focus on other subjects. This situation points out a clear necessity of disseminating such knowledge in order to include these xenarthrans and their relationship with myths into the popular culture.

As previously argued, Jurassic Park film launch was a landmark moment for dinosaur iconography, as well as a change in the popular view of these animals toward more realistic and less monstrous depiction and behavior. Additionally, Figueiroa et al. (2017), while searching for paleontological-related keywords (such as "paleontology," "fossils," "dinosaurs") in Scopus database, noticed a clear increasing trend of papers using these words slightly after (1995) this movie launch, albeit in Brazil (where paleontology is comparatively much less fostered by government than in developed countries) Portuguese equivalents to these words remained rare until 2008. Their research also showed utilization of the term "Paleobotany" (whose first appearance/mention in a movie consists of one line of character Ellie Sattler) has undergone an increasing pattern after the movie. Furthermore, classic scenes (e.g., *Tyrannosaurus* chasing the jeep car) were referenced in many later movies (e.g., Toy Story 2). In addition, Jurassic World box office broke records in its weekend debut (Tartaglione 2015), demonstrating how influential the franchise still is. In line with this, Jurassic Park (1993) has been historically praised by its great cinematographic influence in visual effects, being this aspect recently acknowledged by its induction to the National Film Registry list, which compiles the most significant movies on the basis of its cultural, historical, and/or esthetic value (Kimmelman 2018; Library of Congress 2018). Therefore, we also propose here the recognition of the first Jurassic Park movie as an intangible geoheritage.

Final Considerations on Cultural Geology, Biology, and Taxonomy

Contrary to some perceptions, these just defined fields are not scientific popularization/disclosure/diffusion synonyms. Cultural biology, cultural geology, and cultural taxonomy are responsible chiefly for assessing the cultural impact of geological and biological features in society. Therefore, for example, one may apply cultural taxonomy and cultural paleontology strategies to analyze Jurassic Park iconographic impact on people's perceptions about dinosaurs' external anatomy and ecology. In addition, scientists may or may not teach and disseminate these dinosaurs aspects based on the results provided by the cultural taxonomy and cultural paleontology studies. Although possible and even likeable, cultural biology, geology, and/or taxonomy works do not need a geology/biology teaching or popularization step for being recognized as so. Despite being optional, these fields are also able to improve the geoconservation strategies.

Recently, Dietl (2016) points out paleontology, a generally considered hermetic field, may drive essential strategies to conserve current biodiversity, as conservation paleobiology has essentially the same goals of conservation biology. Therefore, it needs the necessary holistic nature conservation, which requires both, abiotic (e.g., fossil record and outcrops where we found it) and biotic (living organisms) elements in conservation approaches. The geologist Goetel (1966, cited by Gawor 2013) called sozology the interdisciplinary science which aims to conserve nature as a whole (both its biotic and abiotic portions) and its resources. Thus, one may call cultural sozology the scientific field which applies cultural geology and/or cultural biology tools in order to promote a holistic nature conservation. Cultural sozology is not simply combining cultural biology and cultural geology. For instance, we are developing a study which demonstrates that assessing solely geological features (waterfalls) presence in an electronic game may foster combined bio- and geoconservation. Cultural biology is a fast and, at the same time, still slow growing science because, despite lectures on the subject have been promoted throughout Brazil, all of its colloquiums were constrained to the State of Rio de Janeiro. However, its seeds have been planted and evidence of their first blooms is present in this paper by means of the discussions, definitions, and references provided here, along with the cultural geology (and putatively cultural sozology) concept, which is a derivation of the cultural biology one.

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